A Decade with
Swarm-Echo:
Past Discoveries,
Present Status,
and Future Directions

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Swarm 10 Year Anniversary & Science Conference 2024

CASSIOPE becomes Swarm-E

CASSIOPE/e-POP joined Swarm as Swarm-E in 2018

	Swarm-A/C	Swarm-B	Swarm-E
Launch	Nov 2013	Nov 2013	**Sep 2013**
Inclination (deg)	87.4	87.8	**81.0**
Altitude (km)	475	513	**325-1055**
Operations	Continuous	Continuous	**Bursty**

Swarm-E Science Payload (e-POP)

Beacon Transmitter	150/400/1066 MHz	**CERTO**
Auroral Imager	650–1000 nm; 630 nm	**FAI**
GPS Receivers	5 units, L1 and L2	**GAP**
Ion Mass Spectrometer	0.5-70 eV/q; 1-40 amu/q	**IRM**
Magnetometer	Dual mags, 160 samples/s	**MGF**
Radio Receiver	0.01-18 MHz; 31.25 kHz bandwidth	**RRI**
Electron Imager	0.1-350 eV ions or electrons	**SEI**

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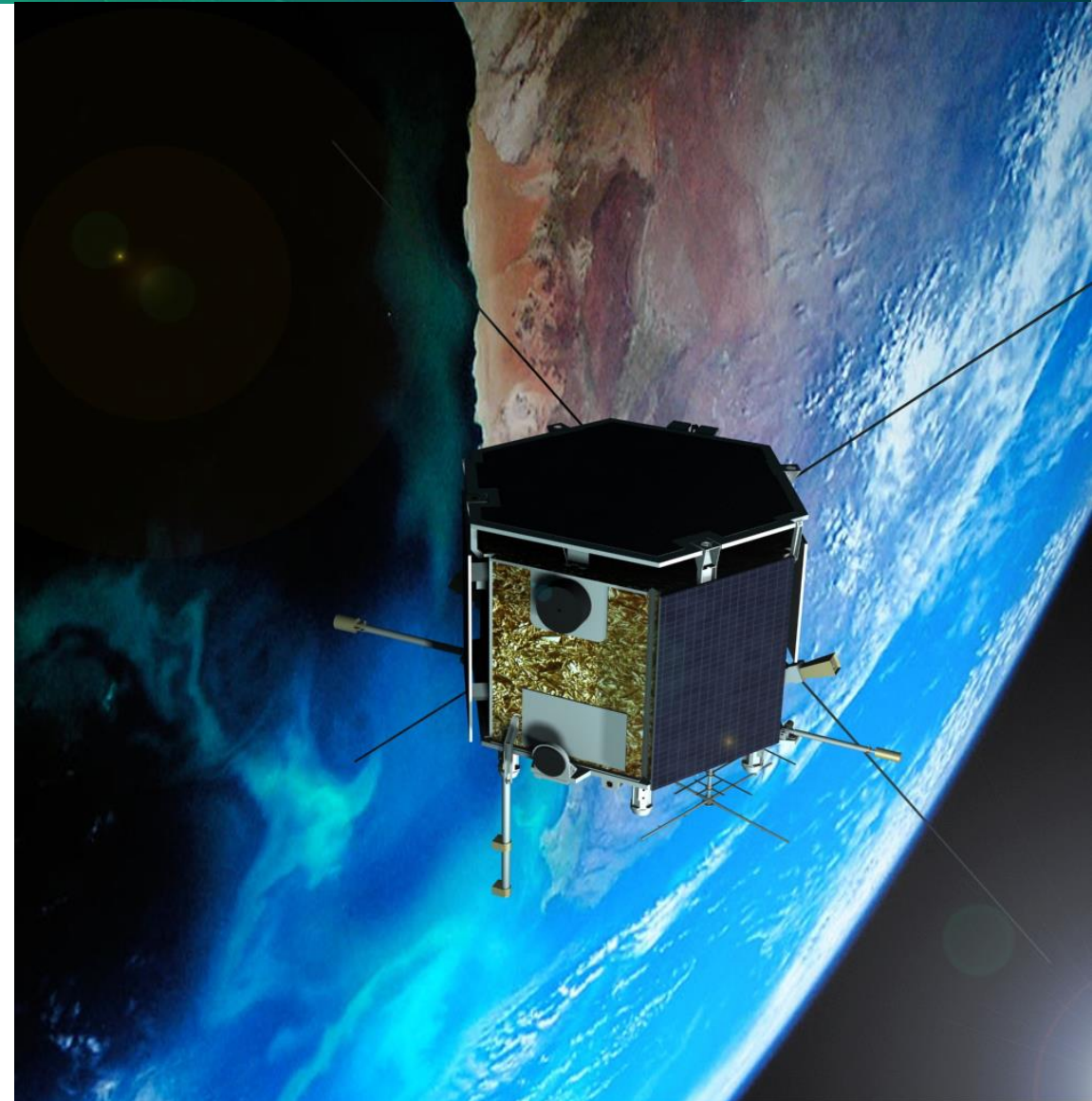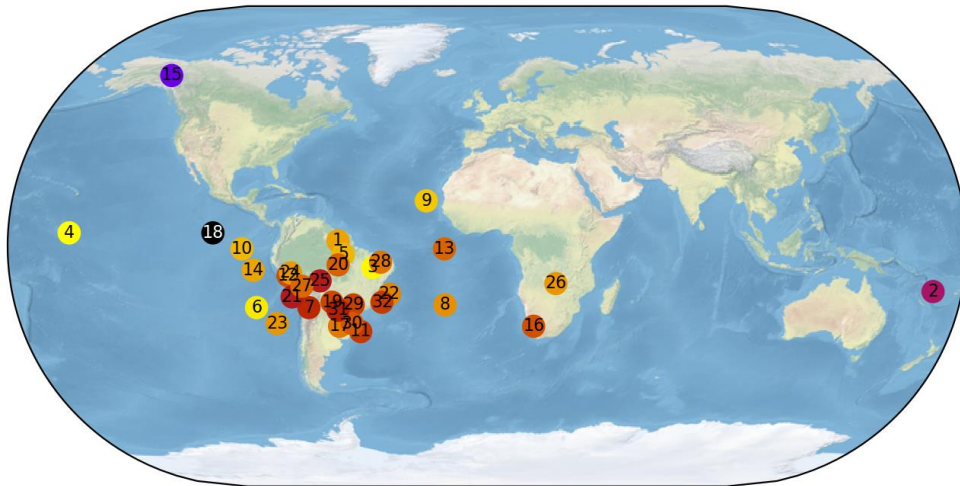
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# Highlights from the last 10 years

- 12 TB of raw and processed data products

- 3000+ close encounters (<400 km) with Swarm-A/B/C

- 400+ passes operating in conjunction with SuperDARN radars

- 118 high-resolution data sets for extremely close (< 5 km) encounters with resident space objects

- 32 spacecraft bus CPU resets caused by single event upsets (high-energy particle strikes)

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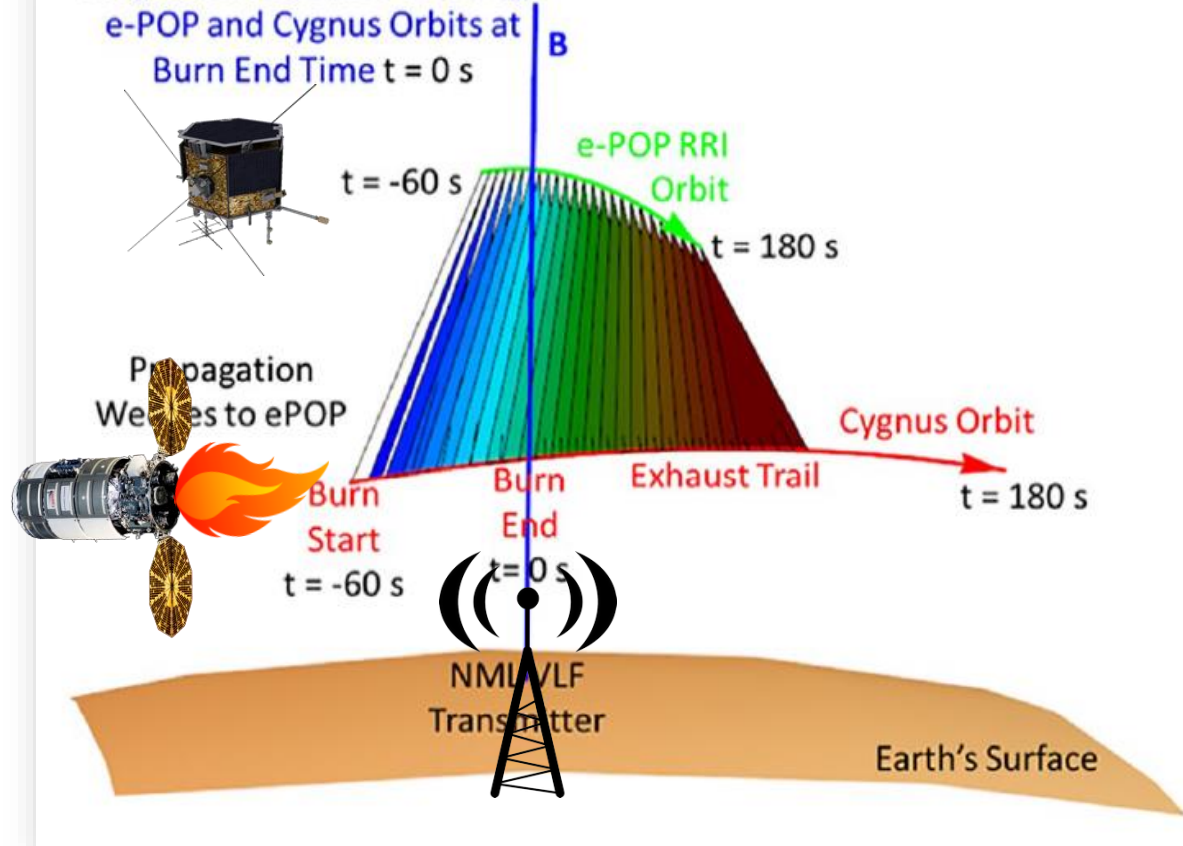
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- Ion mass spectrometer measurements from the 2017 total solar eclipse and the days preceding

- 40% decrease in topside plasma density

- Disruption of upward H+ flow
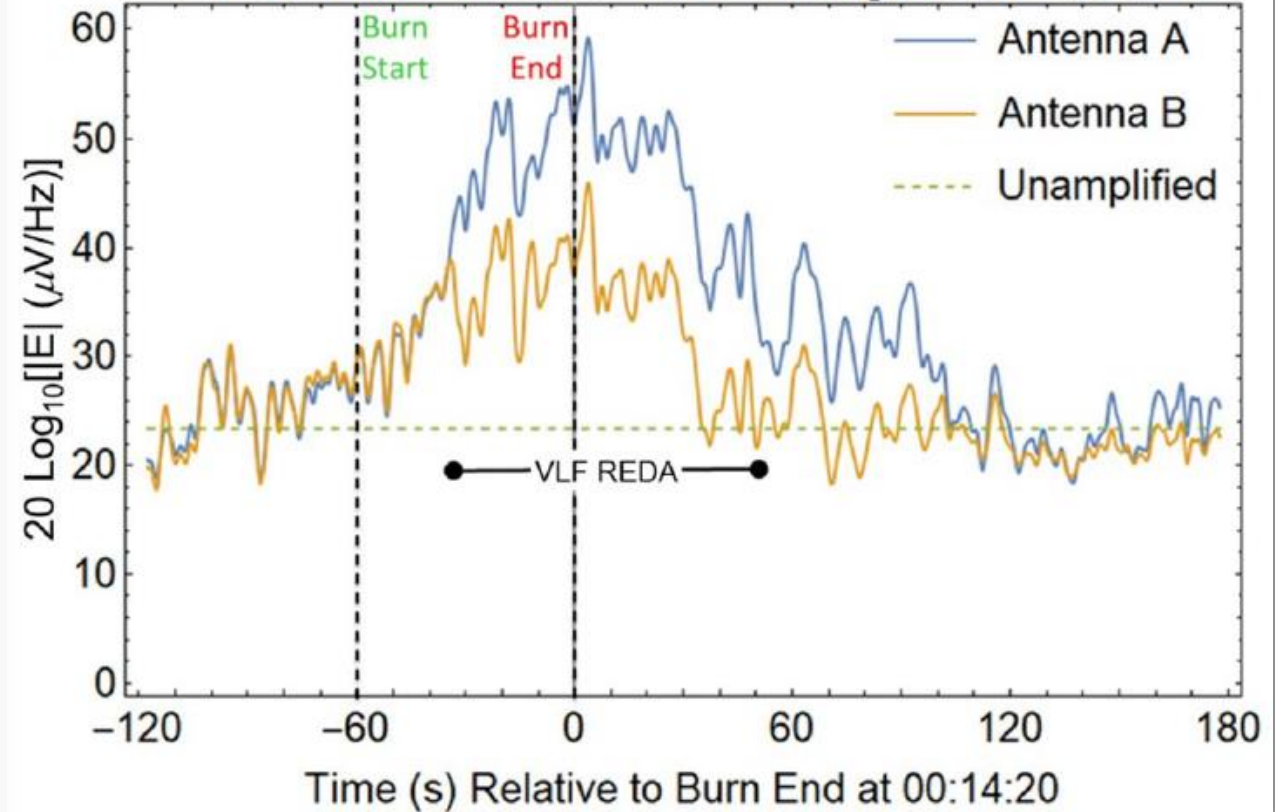
- Changes in the H^+/O^+ composition
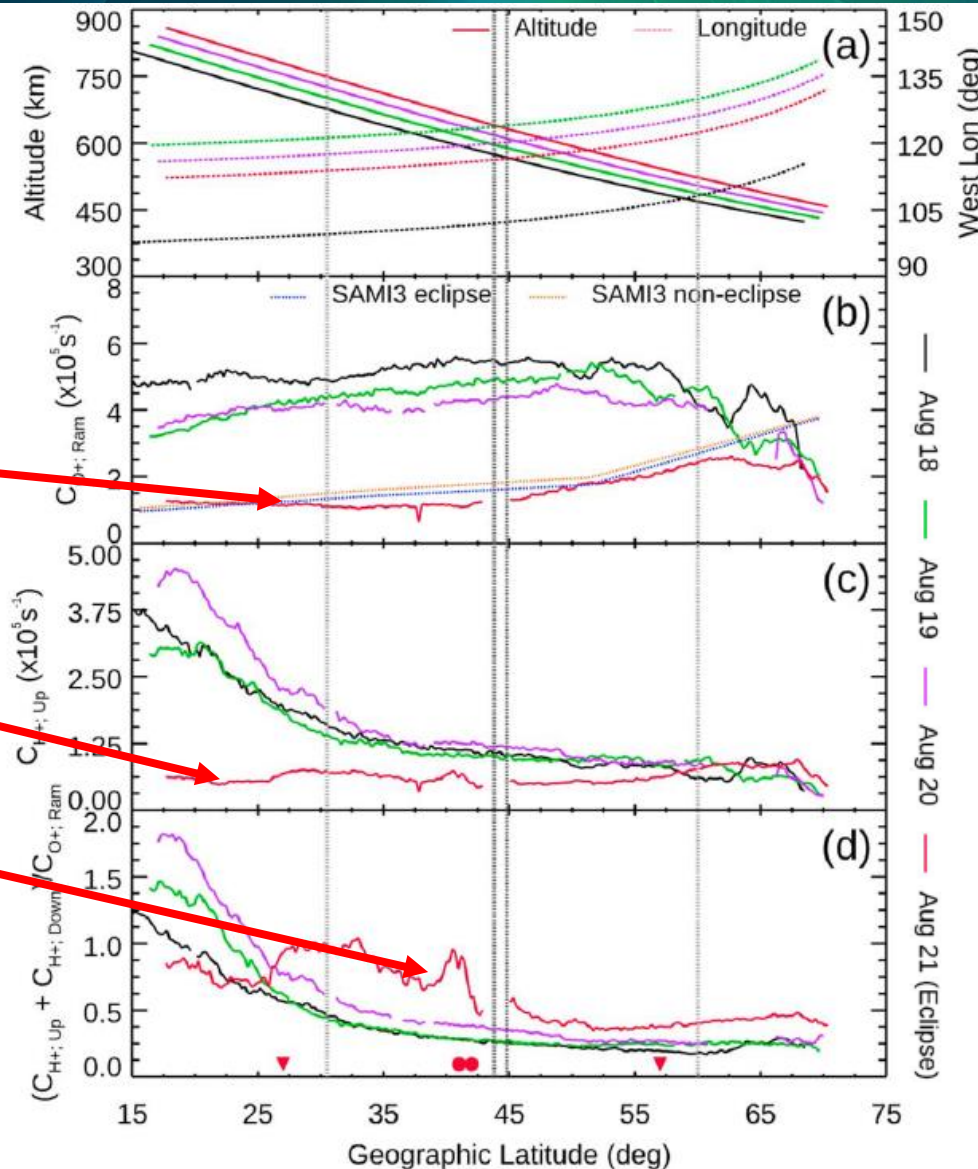
Red line = Eclipse Day

Yau, A. W., Foss, V., Howarth, A. D., Perry, G. W., Watson, C., & Huba, J. (2018). Eclipse-induced changes to topside ion composition and field-aligned ion flows in the August 2017 solar eclipse: e-POP observations. Geophysical Research Letters, 45. https://doi.org/10.1029/2018GL079269

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VLF Amplification

Bernhardt, P. A., Bougas, W. C., Griffin, M. K., Watson, C., Langley, R. B., Howarth, A. D., et al. (2021). Strong amplification of ELF/VLF signals in space using neutral gas injections from a satellite rocket engine. Radio Science, 56, e2020RS007207. https://doi.org/10.1029/2020RS007207
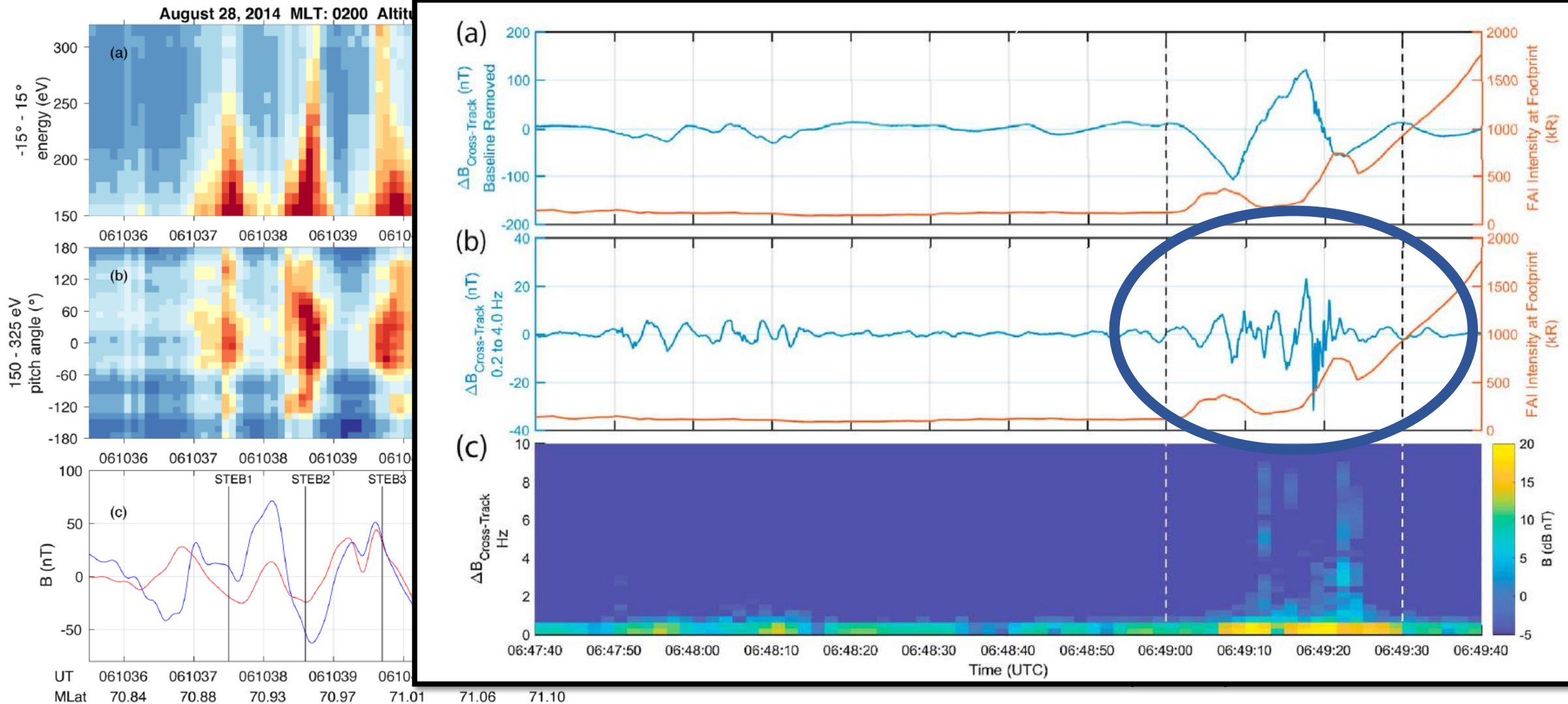
Wu, J., Knudsen, D. J., Shen, Y., & Gillies, D. M. (2021). e-POP observations of Suprathermal electron bursts in the ionospheric Alfvén resonator. Journal of Geophysical Research: Space Physics, 126, e2020JA028005. https://doi.org/10.1029/2020JA028005
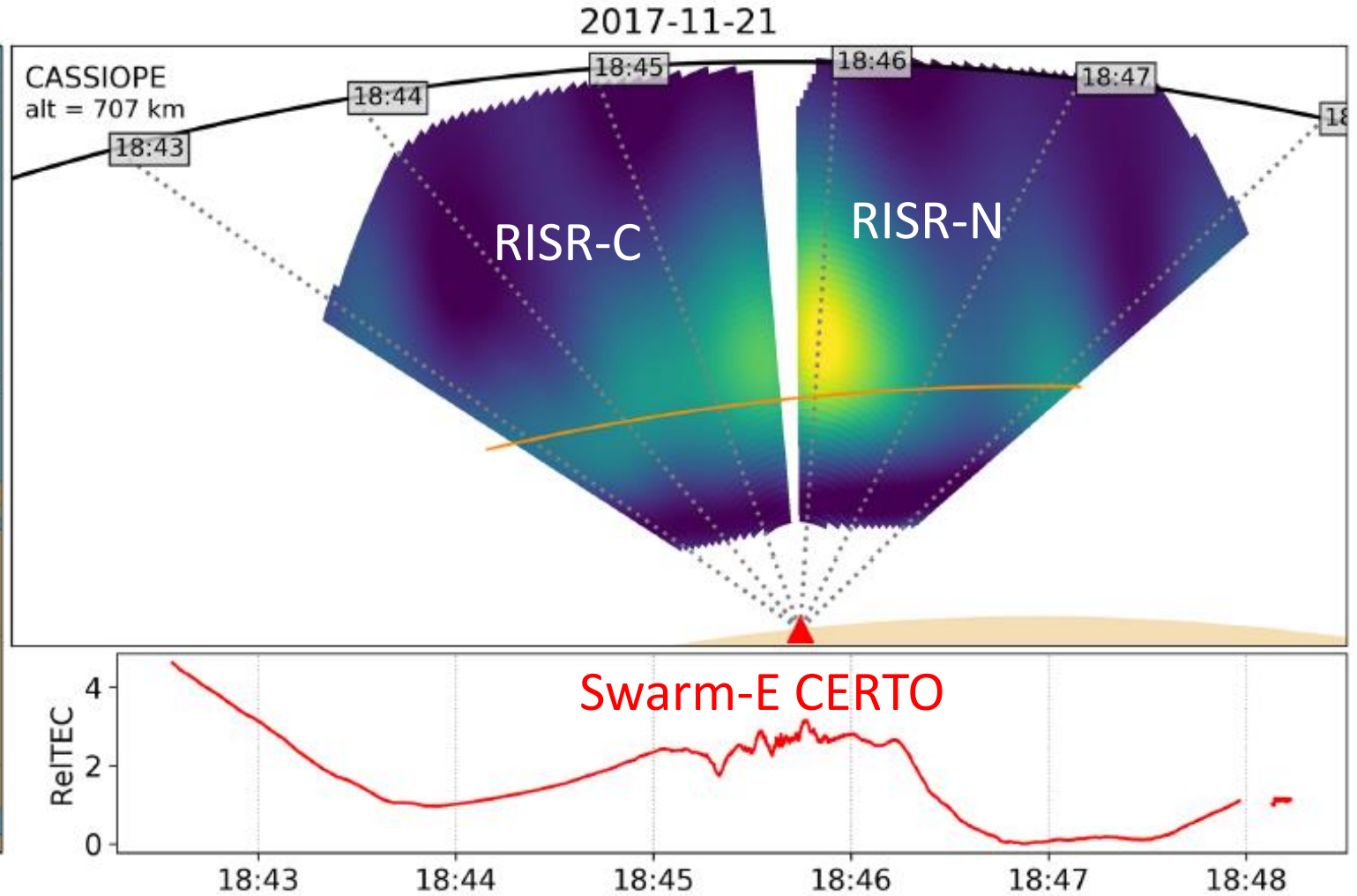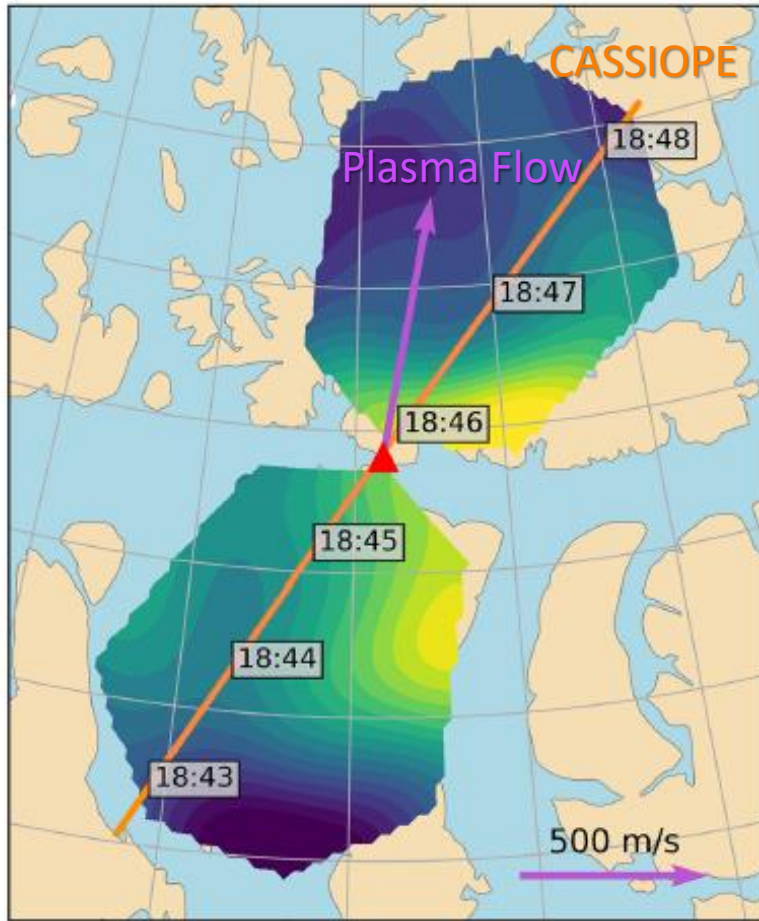
Miles, D. M., Mann, I. R., Pakhotin, I. P., Burchill, J. K., Howarth, A. D., Knudsen, D. J., … Yau, A. W. (2018). Alfvénic dynamics and fine structuring of discrete auroral arcs: Swarm and e-POP observations. Geophysical Research Letters, 45. https://doi.org/10.1002/2017GL076051

- First direct evidence of chorus wave propagation from the magnetosphere to the ionosphere to the ground

- Waves guided by density crests

- Important for relativistic electron precipitation from the radiation belts

Example Chorus Burst in Waveform
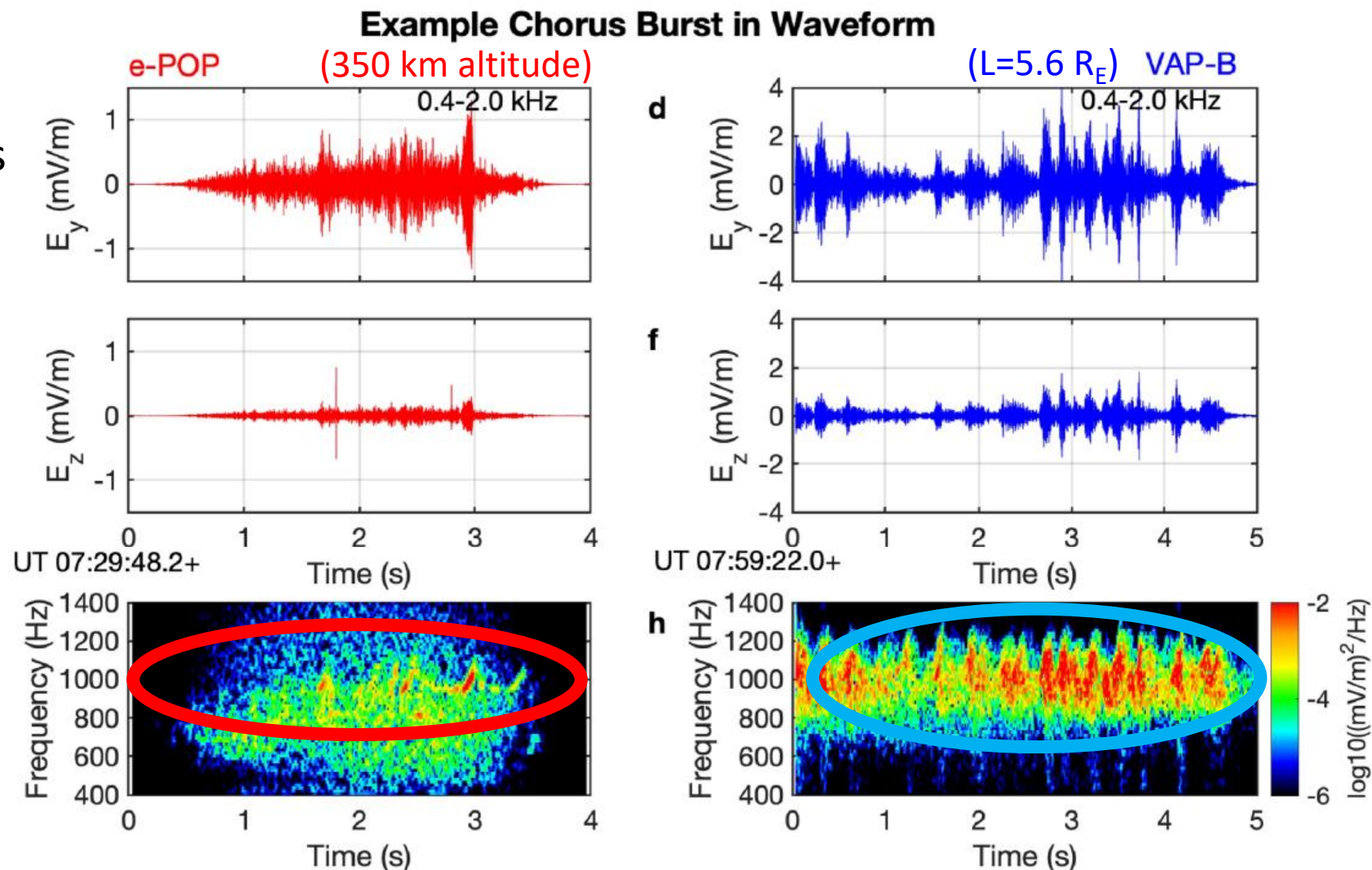
Shen, Y., Chen, L., Zhang, X.-J., Artemyev, A., Angelopoulos, V., Cully, C. M., et al. (2021). Conjugate observation of magnetospheric chorus propagating to the ionosphere by ducting. Geophysical Research Letters, 48, e2021GL095933. https://doi.org/10.1029/2021GL095933

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2017-11-21

CASSIOPE

Plasma Flow

CASSIOPE alt = 707 km

RISR-C

RISR-N

Swarm-E CERTO

Lamarche L. J., Varney, R. H., & Siefring, C. L. (2020). Analysis of plasma irregularities on a range of scintillation-scales using the Resolute Bay Incoherent Scatter Radars. Journal of Geophysical Research: Space Physics, 125, e2019JA027112. https://doi.org/10.1029/2019JA027112

Swarm-E/e-POP Data Tools

- ✓ e-POP Data Handbook

- ✓ e-POP Data Download

- ✓ e-POP Data Explorer (eDEx)

- ✓ e-POP Payload Quicklook

- ✓ e-POP Ephemeris Library

- ✓ e-POP Data Tutorials

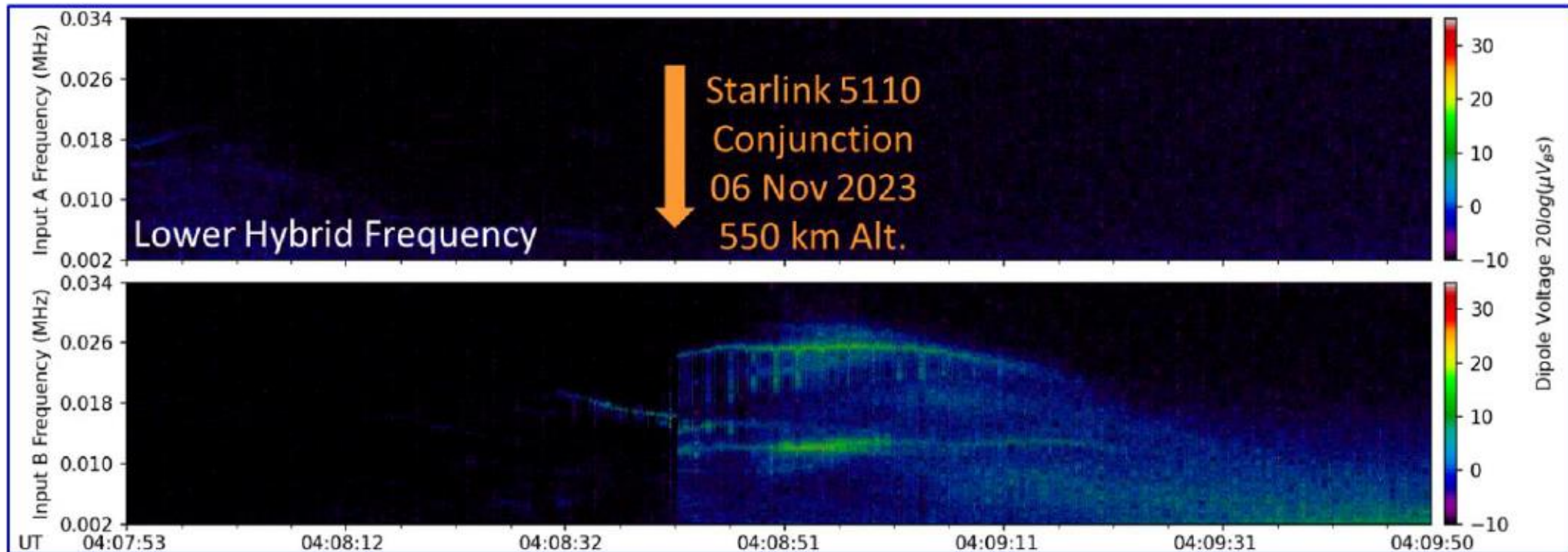## https://epop.phys.ucalgary.ca/data

Present Status

- Swarm-E is still active but not in 'Routine' operations

- Attitude is sub-optimal: solar pointing with 6-minute spin

- Data collection
  - GPS data nearly continuous
  - Close encounters with resident space objects
  - Coordinated experiments with HAARP
  - Other events (e.g. solar eclipse)

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Thank You!

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